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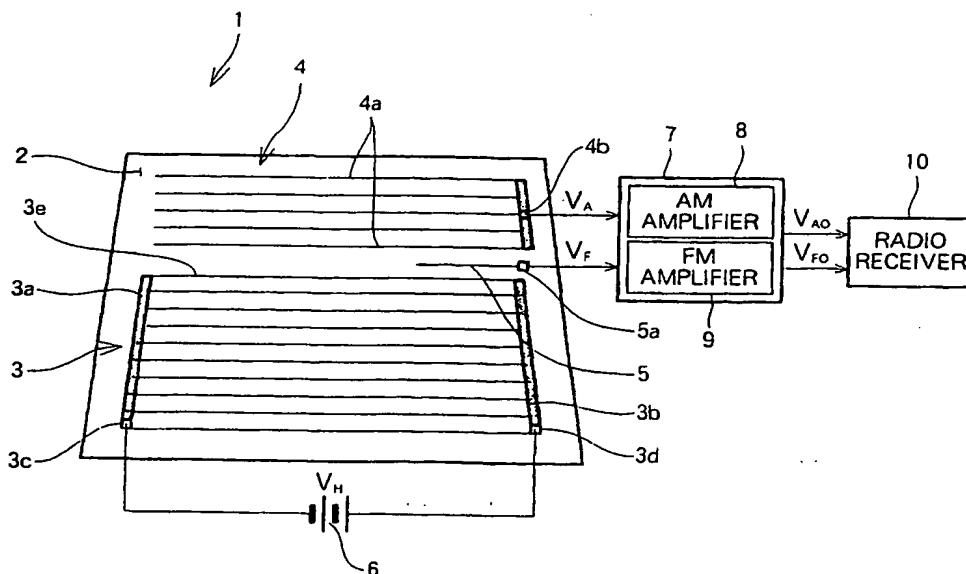
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(54) Title: GLASS ANTENNA DEVICE FOR VEHICLE AND RADIO RECEIVER APPARATUS USING THE SAME



## (57) Abstract

The present invention provides a vehicle glass antenna device which can receive AM and FM waves with high sensitivity without a choke coil and thus facilitates basic designing and adjustment of its antenna patterns. The glass antenna device includes an AM antenna provided so as not to be capacitively coupled with a defogging heater unit also installed on a vehicle window glass. An FM antenna in the form of a single horizontal antenna conductor element is disposed on the window glass between the defogging heater unit and the AM antenna. The glass antenna device further includes an AM amplifier for amplifying a signal received via the AM antenna and an FM amplifier for amplifying a signal received via the FM antenna.

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## DESCRIPTION

GLASS ANTENNA DEVICE FOR VEHICLE AND  
RADIO RECEIVER APPARATUS USING THE SAME

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## Technical Field

The present invention relates to glass antenna devices for use on motor vehicles and radio receiver apparatus using such glass antenna devices.

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## Background Art

Today, glass antenna devices, which comprise antenna conductor elements formed on a window glass of a motor vehicle, are being used more popularly than the traditional rod antennas primarily due to the facts that the glass antenna devices are esthetically superior because they not protrude outside the motor vehicle, they are very unlikely to be damaged, and they do not produce air-cutting sounds.

In many cases, the glass antenna device is installed on a vehicle's rear window glass where a defogging heater unit is provided; thus, the antenna conductor elements must be provided on a limited area of the rear window glass, so as not to overlap the defogging heater unit. Particularly, where the glass antenna device is to be provided for radio communications using the AM, FM, TV, cellular telephone frequency bands, etc., designing and adjusting the glass antenna device tend to be cumbersome and time-consuming work.

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For example, if a same pattern of antenna conductor elements is to be used as a dual-purpose antenna for reception of both AM signals and FM signals, then the antennal pattern would become very complicated in structure (see, for example, Japanese Utility Model Publication No. HEI-1-59309). It has been conventional to adjust such a complicated antenna pattern on a trial-and-error basis, which also tends to be time-consuming work. Especially, because the receiving sensitivity in the AM band is generally proportional to the area occupied by the AM antenna pattern on the vehicle window glass, it is important to reserve a large area for the antenna pattern on the window glass if high receiving sensitivity is to be obtained.

Therefore, it has been proposed to arrange the defogging heater unit to also function as an AM antenna on the vehicle rear window; however, using the defogging heater unit directly as the AM antenna would produce a problem of unwanted noise and thus can not suit practical use.

For that purpose, some of the known vehicle glass antenna devices employ, in between a power source and the defogging heater unit, a choke coil capable of bearing great electric currents so that the heater unit can be used also as an AM antenna, as typically disclosed in Japanese Patent Laid-Open Publication No. SHO-56-42401. In addition, there has been used a dual-purpose glass antenna device capable of receiving both AM signals and FM signals using the above-mentioned arrangements (e.g., Japanese Patent Laid-Open Publication No.

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SHO-57-188102).

However, the provision of the choke coil would require an extra cost and mounting space, so that there has been a demand for a more sophisticated glass antenna device that can  
5 work appropriately with no choke coil.

For example, Japanese Utility Model Publication No. SHO-59-3604 discloses such a sophisticated vehicle glass antenna device. As shown in Fig. 11, the disclosed vehicle glass antenna device 101 is installed on a vehicle rear window glass  
10 102 and includes an AM antenna 104 provided above a defogging heater unit or defogger 103. In this glass antenna device, the defogger 103 is arranged to also function as an FM antenna 105, and the AM antenna 104 and FM antenna 105 are connected to a radio receiver apparatus (not shown) via respective amplifiers  
15 108 and 109. The defogger 103 and a power feeding point 105b are connected in series with each other via a lead 120.

The No. SHO-59-3604 publication has a description which reads "the above-mentioned defogger is connected to a lead of a suitable length such that an impedance matching is effected  
20 to allow the defogger to work as an FM antenna section". No subsidiary FM antenna is provided in the vehicle glass antenna device according to the No. SHO-59-3604 publication.

Importantly, no choke coil is provided between the defogger 103 and a power source 106 in the vehicle glass  
25 antenna device of the No. SHO-59-3604 publication. However, in this disclosed vehicle glass antenna device, a large space can not be allocated to the AM antenna; thus, an amplifier is used

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here to enhance the receiving sensitivity of the AM antenna installed in the limited space.

Further, U.S. Patent No. 4,791,426 discloses an antenna device provided on a rear window glass of a motor vehicle. As shown in Fig. 12, the disclosed antenna device 201 includes an antenna 204 for reception of long-wave, medium-wave and short-wave signals, and a plurality of defogging heater elements 203 capable of also functioning as an antenna 205 for reception of ultra-short-wave signals. The signals received via the antennas 204 and 205 are coupled via respective amplifiers 208 and 209 to a radio receiver apparatus (not shown). In Fig. 12, reference numeral 210 represents a frequency separator.

Further, as regards an amplifier circuit for use in a glass antenna, Japanese Patent Laid-open Publication No. SHO-53-97353 teaches an antenna device where a field effect transistor is connected to a glass antenna and used as a preamplifier to minimize spurious reception.

The above-discussed vehicle window glass antenna devices of Japanese Patent Laid-Open Publication Nos. SHO-56-42401 and SHO-57-188102 and U.S. Patent No. 4,791,426 all employ a choke coil between a bus bar and a D.C. power source. The provision of the choke coil, however, would present the problems that the antenna device can not be readily installed in a limited space of a vehicle window glass and the overall costs of the antenna device increase due to the extra cost of the choke coil.

Furthermore, in U.S. Patent No. 4,791,426, the defogger is used also as the FM antenna, which, however, is not

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practical because power is supplied to the defogger directly from the power feeding point 205b and thus a sufficient FM receiving sensitivity can not be attained.

In the antenna device of Japanese Utility Model  
5 Publication No. SHO-59-3604, the defogger is used as the FM  
antenna 105 without such a choke coil provided between the  
defogger and the power source. Unlike in the AM frequency  
band, the defogger may be allowed to operate properly in the FM  
frequency band without the provision of the choke coil.  
10 However, because the defogger and power feeding point 105b are  
connected directly by the lead 120, there would arise the  
problem that a sufficient FM receiving sensitivity can not be  
attained. Thus, currently, the antenna device as disclosed in  
Japanese Utility Model Publication No. SHO-59-3604 has not yet  
15 been put to actual use. In addition, as shown in Fig. 11, the  
lead 120 has a length greater than one half of the width of the  
window glass.

Moreover, with the above-discussed vehicle window glass  
antenna devices provided with amplifiers, the amplifiers may  
20 produce an unwanted distortion in their output FM signals due  
to an excessive gain when the input or received FM signals are  
of high level (great electric field intensity). In addition,  
when received FM signals having similar or close frequencies  
are amplified, the glass antenna devices with amplifiers would  
25 present the problem that, these FM signals may be mutually  
modulated with each other and a resultant mutually-modulated  
signal, corresponding to a difference between the close

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frequencies, may assume a frequency belong to the AM frequency band and thereby exert undesired influences on the reception of FM signals.

Further, with the vehicle window glass antenna device disclosed in U.S. Patent No. 4,791,426, there is a need to use a low-capacity, thick and heavy coaxial cable. Such a thick and heavy coaxial cable provides a very poor handling flexibility and thus is difficult to lay in place, thereby presenting a significant obstacle to assemblage of the antenna device.

Further, due to the fact that a combination of required signal receiving performance and signal receiving band, as well as a vehicle body shape, differs for each type of motor vehicle, it has been necessary to design a different glass antenna for each motor vehicle type, which would take much time and labor.

In addition, in the case where a combination AM and FM antenna pattern is to be employed, a great amount of time would generally have to be spent in adjusting the antenna pattern before and after actual use thereof.

Besides, even with motor vehicles of a same type, it is normally necessary to modify the antenna pattern in case available frequency bands differ among places to which the vehicles are shipped (i.e., destinations) and adjust the antenna pattern depending on presence/absence of a rear windscreen wiper, which would take even greater time and labor.

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Furthermore, in view of the fact that the time period allocated for developing motor vehicles has been made shorter and shorter these days, there is a demand that the time period for adjusting the design of the glass antenna using an actual  
5 vehicle body be shortened at the development stage of the glass antenna.

Therefore, there is currently a demand for an improved vehicle window glass antenna device which can be applied to various different types of motor vehicles without the basic  
10 design of its antenna pattern having to be changed and is thus readily adjustable in accordance with the various different types of motor vehicles.

#### Disclosure of the Invention

15 In view of the foregoing, it is a first object of the present invention to provide a vehicle window glass antenna device which is cable of receiving AM and FM waves with high sensitivity without using a choke coil.

It is a second object of the present invention to  
20 provide a vehicle window glass antenna device which can be used appropriately in various places or destinations by just modifying its frequency setting. It is yet another object of the present invention to provide a vehicle window glass antenna device which can be applied appropriately to various types of  
25 motor vehicles, without a need to change the basic design of its antenna pattern, as long as the size and mounting areas of the window glass are similar between the vehicle types.

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It is a third object of the present invention to provide a vehicle window glass antenna device which does not produce an unwanted signal distortion in response to an input signal of a strong electric field and which can avoid a mutual modulation  
5 between received FM signals of close frequencies.

It is a fourth object of the present invention to provide a vehicle window glass antenna device in which there can be employed a thin coaxial cable that is easy to handle and lay in position.

10 According to one aspect of the present invention, there is provided a vehicle window glass antenna device which comprises: a defogging heater unit provided on a window glass of a vehicle; an AM antenna provided above the defogging heater unit for receiving a signal of an AM frequency band; an FM  
15 antenna provided between the defogging heater unit and the AM antenna for receiving a signal of an FM frequency band, the FM antenna comprising a single horizontal antenna conductor element; an AM amplifier for amplifying the signal received via the AM antenna; and an FM amplifier for amplifying the signal  
20 received via the FM antenna.

In the vehicle window glass antenna device of the present invention, the defogging heater unit is capacitively coupled with the FM antenna to function as a subsidiary FM antenna.

25 The vehicle window glass antenna device of the present invention may further comprise a separate subsidiary FM antenna provided below the defogging heater unit. In this case, the

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subsidiary FM antenna constitutes a diversity antenna with the above-mentioned FM antenna provided between the defogging heater unit and the AM antenna functioning as a main antenna.

The AM antenna employed in the inventive vehicle window glass antenna device may comprise a plurality of horizontal antenna conductor elements. Preferably, the horizontal antenna conductor elements of the AM antenna each have a length in the range of 800 mm to 1,300 mm. The AM antenna may also include a short-circuiting line interconnecting the plurality of horizontal antenna conductor elements.

Further, the defogging heater unit may comprise a plurality of heater lines and a short-circuiting line interconnecting these heater lines.

It is preferred that the AM amplifier comprise an electric circuit including a common-source FET (Field Effect Transistor) and have an input impedance of at least 1 M $\Omega$ . The AM amplifier may include a choke coil provided at its output stage and have an output impedance of 100  $\Omega$  or less.

In a preferred implementation, the FM amplifier comprises an electric circuit including a grounded-base transistor or grounded-gate FET. Preferably, the FM amplifier has an input impedance of 50  $\Omega$  or less. Further, the FM amplifier preferably has a gain of 3 dB or less. In addition, the FM amplifier may include, at its output stage, a filter in the form of a tank circuit which acts to prevent generation of a mutually-modulated signal of the AM frequency band through a mutual modulation between a plurality of output FM signals from

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the FM amplifier.

According to another aspect of the present invention, there is provided a radio receiver apparatus for a vehicle which comprises: a defogging heater unit provided on a window glass of a vehicle; an AM antenna provided above the defogging heater unit for receiving a signal of an AM frequency band; an FM antenna provided between the defogging heater unit and the AM antenna for receiving a signal of an FM frequency band, the FM antenna comprising a single horizontal antenna conductor element; an AM amplifier for amplifying the signal received via the AM antenna; an FM amplifier for amplifying the signal received via the FM antenna; and a radio receiver connected with respective output terminals of the AM amplifier and FM amplifier via a signal-transmitting cable having a diameter of 3 mm or less.

In the radio receiver apparatus of the present invention, it is preferred that the signal-transmitting cable have an impedance of 75  $\Omega$  or less.

The present invention is based on the following basic designing policies.

First of all, each of the AM and FM antennas is designed as a dedicated simple antenna pattern so that basic designing and adjustment of the AM and FM antennas can be substantially facilitated.

Second, the defogging heater unit is equipped with no choke coil and therefore can not be used as an AM antenna in the present invention. Thus, a separate AM antenna pattern

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having as large an area as possible is provided in a space above the defogging heater unit in such a manner that the AM antenna pattern is not capacitively coupled with the defogging heater unit.

5           Lowering the impedance of the AM antenna is very effective in enhancing the receiving sensitivity of the AM antenna. To lower the impedance of the AM antenna, it is preferred that the area and length of the AM antenna conductor pattern be maximized so as to provide a greatest possible  
10 antenna capacity. This is why the AM antenna pattern having as large an area as possible is provided in a space above the defogging heater unit in such a manner that the AM antenna pattern is not capacitively coupled with the defogging heater unit.

15           Because there is not a very great available space above the defogging heater unit on the vehicle window glass, it is preferred that the AM antenna comprise a plurality of horizontal antenna conductor elements connected together to constitute a fork-shaped AM antenna pattern. Alternatively,  
20 the AM antenna may comprise a plurality of antenna conductor elements connected to form a loop-shaped AM antenna pattern. It is also preferred that the fork-shaped or loop-shaped AM antenna pattern include a short-circuiting line extending centrally across the antenna pattern.

25           Further, to improve the receiving sensitivity of the AM antenna provided in the limited space above the heater unit, it is necessary to minimize the reception loss of the antenna; to

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this end, there is a need to feed power separately to the AM and FM antennas.

In this case, it is preferable that the AM antenna pattern have as large an area as possible, as noted earlier.

5 Flexibility in choosing a vertical dimension of the AM antenna pattern is limited inevitably by factors such as the size of the vehicle window glass, region where the defogging heater unit is installed and necessary spacings between the AM antenna, FM antenna and defogging heater unit. Thus, to

10 maximize the area of the AM antenna pattern as desired, the horizontal dimension or length of the antenna pattern has to be increased.

But, it is also important to make arrangements for preventing the AM antenna from adversely influencing the

15 receiving sensitivity of the FM antenna. Experiments have shown that a desirable horizontal dimension of the AM antenna pattern that will not adversely influence the receiving sensitivity of the FM antenna is in the range of 800 mm - 1,300 mm and more preferably 900 mm - 1,200 mm.

20 In the present invention, the FM antenna is constructed as follows.

Namely, the inventive glass antenna device includes a single horizontal FM antenna conductor element disposed between the defogging heater unit and the AM antenna. The reasons why

25 the FM antenna comprises only one horizontal antenna conductor element are to make the shape of the FM antenna as simple as possible in order to facilitate necessary adjustment of the FM

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antenna, and to make the area of the FM antenna as small as possible in order to allow the area of the AM antenna to be maximized.

In a preferred implementation of the invention, the length of the above-mentioned FM antenna is determined in accordance with the following mathematical expression:

$$L_{FM} = \lambda / 4 \times \text{contraction ratio} \quad \text{Expression (1)}$$

, where  $\lambda$  represents a designed wavelength. As may be known, the FM frequency band is 76 - 90 MHz in Japan and 88 - 108 MHz in North America, and the designed wavelength is selected from among such FM frequency bands. Here, the "contraction ratio" can generally be defined by the following mathematical expression:

$$\text{contraction ratio} = (\text{electrical wavelength reflecting a dielectric effect} / \text{free-space wavelength}) \times 100(\%)$$

Expression (2)

Generally, in the glass antennas, an antenna pattern is provided on a dielectric substance in the form of a glass sheet. Thus, the dielectric effect produced by the glass sheet allows the antenna pattern to work effectively even when the pattern length is shorter than a given length calculated on the basis of the wavelength  $\lambda$ .

It is also preferred that the FM antenna pattern be capacitively coupled with the defogging heater unit. Note that the inventive glass antenna device includes no choke coil between the defogging heater unit and a power source. However, in the inventive glass antenna device where the FM antenna

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pattern and defogging heater unit are capacitively coupled with each other, there would not arise the inconveniences as presented by the device of Japanese Utility Model Publication No. SHO-59-3604 having been discussed earlier, and the  
5 defogging heater unit can be used appropriately as a subsidiary FM antenna. As a consequence, the inventive glass antenna device achieves an enhanced FM-wave receiving sensitivity. Because the FM antenna pattern and defogging heater unit are capacitively coupled with each other, the above-mentioned  
10 contraction ratio must be determined taking the antenna's coupling capacitance into account.

The FM antenna employed in the inventive glass antenna device comprises only a single horizontal antenna conductor element that is therefore very simple in construction. Thus,  
15 the vehicle window glass antenna device of the invention can be used appropriately in various places or destinations of different frequency bands, by just modifying its frequency setting and changing the length of the FM antenna. Namely, with the inventive vehicle window glass antenna device, there  
20 is no need to change or adjust the shape of the FM antenna.

Further, if necessary, there may be provided a subsidiary FM antenna below the defogging heater unit on the vehicle window glass. In this case, the subsidiary FM antenna may be constructed to function as a diversity antenna with the  
25 FM antenna provided between the defogging heater unit and the AM antenna functioning as a main antenna. Preferably, such a subsidiary FM antenna comprises a single horizontal antenna

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conductor element, for the same reason as stated above in relation to the main FM antenna. The subsidiary FM antenna may also be capacitively linked with the defogging heater unit. The length of this subsidiary FM antenna may also be determined  
5 in the same manner as set forth above in relation to the main FM antenna.

To enhance the FM-wave receiving sensitivity, it is preferred that the defogging heater unit include a short-circuiting line extending substantially centrally across its  
10 heater elements or lines to interconnect the heater lines at their substantial central points. The short-circuiting line acts to control coupling, in a high-frequency operating state, of distributed capacitance of the main FM antenna, defogging heater unit and subsidiary FM antenna, to thereby enhance the  
15 overall receiving sensitivity of the FM antennas. Two or more short-circuiting lines, rather than just one, may be provided in the defogging heater unit.

The AM amplifier employed in the inventive glass antenna device is constructed as follows.

20 In the inventive glass antenna device, the defogging heater unit occupying a large area on the window glass is not constructed to also function as an AM antenna, and therefore a separate AM antenna is provided in the limited space above the defogging heater unit. Thus, the separate AM antenna can not  
25 have a sufficiently large area, so that the receiving voltage can not be increased sufficiently. The AM amplifier is provided to make up for the shortage of the receiving voltage.

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In the inventive glass antenna device, the AM amplifier comprises a semiconductor element such as a transistor or FET, resistor, coil and capacitor, so as to amplify a received signal of the AM frequency band and match input and output  
5 impedances of the amplifier. It is preferred that the AM amplifier has a high output impedance and a low output impedance. For that purpose, a high-frequency transformer may be provided at the output stage of the AM amplifier, so as to cause the output impedance to be 1,000  $\Omega$  or less.

10 On the other hand, the FM amplifier employed in the inventive glass antenna device is constructed as follows.

The FM amplifier comprises a semiconductor element such as a transistor or FET, resistor, coil and capacitor, so as to amplify a received signal of the FM frequency band and match  
15 input and output impedances of the amplifier. It is preferred that the FM amplifier have low noise in order to increase its S/N ratio. Further, in order to properly receive an input signal of great electric field intensity, it is also preferred that the FM amplifier comprise a grounded-gate circuit using a  
20 low-noise FET and be set to a gain of 3 dB (i.e., an amplification rate of one) or less. Preferably, the FM amplifier has an input impedance of 50  $\Omega$  or less.

It is also preferred that the FM amplifier include, at its output stage, a filter in the form of a tank circuit which  
25 can prevent generation of a mutually-modulated signal of the AM frequency band through a mutual modulation between a plurality of output FM signals from the FM amplifier. Alternatively, the FM amplifier may comprise a grounded-base circuit using a low-

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noise transistor.

As set forth above, the inventive glass antenna device is characterized in that it includes dedicated FM and AM antennas and dedicated amplifiers are provided respectively for the FM and AM antennas; thus, the inventive glass antenna device can receive both FM-wave signals and AM-wave signals with superior sensitivity.

In addition, in the vehicle radio receiver apparatus employing the inventive glass antenna device, the AM and FM amplifiers can be set to sufficiently low output impedances, which allows the antenna device to be connected to the radio receiver apparatus using a signal-transmitting cable having a diameter of just 3 mm or less. Such a signal-transmitting cable (typically, a coaxial cable) having a diameter of 3 mm or less is very pliable and can be handled with utmost ease, so that the coaxial cable can be readily laid in place on the vehicle. Specific examples of the signal-transmitting cable include ones commonly known as "1.5C2N" (about 2.3 mm in diameter) or "1.5C2V" or "1.5C2E" (about 2.9 mm in diameter) (applicable standard: JIS C 3501).

#### Brief Description of the Drawings

Fig. 1 is a diagram showing a basic structure of a vehicle window glass antenna device in accordance with an embodiment of the present invention.

Fig. 2 is a diagram showing a basic structure of a vehicle window glass antenna device in accordance with another embodiment of the present invention.

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Fig. 3 is a diagram showing a basic structure of a vehicle window glass antenna device in accordance with still another embodiment of the present invention.

Fig. 4 is a circuit diagram illustrating an embodiment of an AM amplifier employed in the present invention.

Fig. 5 is a graph showing variations in noise that occur as the value of a gate resistance is varied.

Fig. 6 is a circuit diagram illustrating an embodiment of an FM amplifier employed in the present invention.

Fig. 7 is a block diagram showing a basic construction of a synthesizer section employed in the present invention.

Fig. 8 is a diagram illustrating an exemplary circuit organization of the synthesizer section.

Fig. 9 is a view showing a specific example of antenna patterns employed in the vehicle window glass antenna device of the present invention.

Figs. 10A and 10B are diagrams explanatory of two different FM antenna constructions selectively usable depending on presence/absence of a connecting lead.

Fig. 11 is a diagram explanatory of a prior art glass antenna device (Japanese Utility Model Laid-open Publication No. 59-3604).

Fig. 12 is a diagram explanatory of another prior art glass antenna device (U.S. Patent No. 4,791,426).

#### Best Mode for Carrying Out the Invention

Several preferred embodiments of the present invention will be described hereinafter with reference to the

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accompanying drawings.

Referring first to Fig. 1, a vehicle window glass antenna device 1 includes the following components provided on a window glass (e.g., rear window glass) 2 of a motor vehicle. Namely, the glass antenna device 1 includes a dedicated AM antenna 4, a dedicated FM antenna 5 and a defogging heater unit 3 in the form of a printed conductor pattern.

The vehicle window glass antenna device 1 also includes an amplification section 7 for amplifying input AM and FM signals  $V_A$  and  $V_F$  received via the AM and FM antennas 4 and 5 (hereinafter called "received AM and FM signals"), respectively, and a radio receiver apparatus 10 that reproduces amplified AM and FM signals  $V_{AO}$  and  $V_{FO}$  output from the amplification section 7 (hereinafter called "output AM and FM signals").

The motor vehicle is also provided with a heater power source 6 for heating the defogging heater unit 3.

The defogging heater unit 3 includes a pair of opposed bus bars 3a and 3b disposed and extending along left and right side edges of the vehicle window glass, power feeding patterns 3c and 3d for coupling the heater power source 6 to the respective bus bars 3a and 3b, and a plurality of horizontal heater elements 3e extending between the opposed bus bars 3a and 3b.

As D.C. power  $V_H$  is fed from the heater power source 6, such as a battery, via the feeding patterns 3c and 3d to the defogging heater unit 3, a heater current, whose value is determined by a voltage  $V_H$  between the bus bars 3a and 3b and

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respective resistance values of the heater elements 3e, flows through the defogging heater unit 3 to thereby resistively heat the heater elements 3e. Thus, the defogging heater unit 3 is heated and causes condensation on the window glass 2 to evaporate, so as to defog the window glass surface.

Note that the defogging heater unit 3 in this embodiment is connected directly to the heater power source 6 via the feeding patterns 3c and 3d. In this way, the defogging heater unit 3 can present a low impedance to an AM wave and is prevented from functioning as an AM antenna.

The following paragraphs describe the AM antenna 4 employed in the antenna device.

The AM antenna 4 in this embodiment comprises a plurality of AM antenna conductor elements extending horizontally in a region between the uppermost heater element 3e of the defogging heater unit 3 and the top edge of the window glass 2; these AM antenna conductor elements 4a together constitute a fork-shaped AM antenna pattern. The AM antenna receives an AM wave by means of the antenna conductor elements 4a and supplies a received AM signal  $V_A$  to an AM amplifier 8 of the amplification section 7 via the AM feeding pattern 4b.

The reason why the AM antenna 4 is constructed of the plurality of horizontal AM antenna conductor elements is that the receiving sensitivity to the incoming AM wave depends on a total area of the AM antenna pattern 4a and it is preferable that the total area of the AM antenna pattern 4a be as large as possible and the AM antenna conductor elements 4a be formed into a simple antenna pattern.

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In the specific illustrated example, the AM antenna 4 is constructed of five horizontal AM antenna conductor elements each having a length  $L_{AM}$  of 1,000 mm and spaced from each other by about 20 mm.

5 The 1,000 mm length  $L_{AM}$  is a value determined such that the AM antenna 4 does not exert adverse influences on the receiving sensitivity of the FM antenna 5.

As one of the essential designing features of the present invention, each of the AM and FM antennas 4 and 5 is  
10 designed as a dedicated simple antenna pattern, so as to minimize interferences between the AM antenna and the FM antenna. However, a certain degree of such interferences may be unavoidable due to the fact that the AM and FM antennas and defogging heater unit are all provided on the rear window glass  
15 having a limited area.

To verify the advantageous effects achieved by the foregoing arrangements of the present invention, TABLE 1 is given below which shows measurements of the receiving sensitivity of the FM antenna in relation to EXAMPLE 1 where  
20 each of the AM antenna conductor elements is set to the 1,000 mm length  $L_{AM}$  and EXAMPLE 2 where each of the AM antenna conductor elements is set to a maximum length.

TABLE 1

25	EXAMPLE	$L_{AM}$ (mm)	FM-signal Receiving Sensitivity
	1	1,000	48 dB $\mu$ V
	2	1,400	45 dB $\mu$ V

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From TABLE 1 above, it can be seen that less influences are exerted on the FM antenna in Example 1 than in EXAMPLE 2. Note that the influences exerted on the FM antenna in EXAMPLE 2 are not of such a level that would lead to inconveniences in  
5 actual use.

It is preferred that the AM antenna 4 be spaced from the uppermost heater element 3e by more than a predetermined distance (e.g., 30 mm) so that it can be reliably prevented from being capacitively linked with the defogging heater unit  
10 3. Further, the AM antenna's receiving sensitivity to the AM wave can be set to a desired value by coupling the heater power source 6 directly to the power feeding patterns 3c and 3d to thereby set the impedance of the heater pattern 3e to a value low enough to significantly reduce electrical coupling from the  
15 defogging heater unit 3.

Now, the following paragraphs describe the FM antenna  
5.

The FM antenna 5 comprises a single horizontal antenna conductor element positioned between the uppermost heater  
20 element of the defogging heater unit 3 and the AM antenna 4. The FM antenna 5 supplies a received FM signal to an FM amplifier 9 of the amplification section 7 via the FM feeding pattern 5a.

In the present invention, the FM antenna 5 is not  
25 directly connected with the defogging heater unit 3, but it is preferred that the FM antenna 5 be capacitively linked with the defogging heater unit 3. For example, it is preferable that a distance from the FM antenna 5 to the uppermost heater element

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of the defogging heater unit 3 be set to a predetermined value (e.g., in the range of 5 mm - 10 mm) so that the FM antenna 5 is capacitively linked with the heater unit 3 (see Fig. 2).

In the specific illustrated example, the FM antenna 5 is set to a length  $L_{FM}$  ranging from 300 mm to 500 mm. However, the length  $L_{FM}$  is varied depending on a particular way of power feeding to the FM antenna, i.e., whether (a) the FM feeding pattern 5a on the window glass is used as the power feeding point or (b) the FM feeding pattern 5a is connected via a connecting lead to the FM amplifier 9 and the connection point therebetween is used as the power feeding point. In the latter case, the connecting lead functions also as an FM antenna conductor element and the FM feeding pattern functions only as a mere connecting pattern.

15 In the (a) case above, it is preferable that the length  $L_{FM}$  of the FM antenna be set, on the basis of a designed wavelength, in accordance with mathematical expression (1) above.

In the (b) case, on the other hand, it is necessary that 20 the FM antenna be set to a length calculated by subtracting the length of the connecting lead from the designed length  $L_{FM}$ . Namely, the length of the FM antenna 5 formed on the window glass has to be made smaller as the length of the connecting lead increases.

25 Further, it is preferred that the FM antenna 5 be spaced from the AM antenna 4 by more than a predetermined distance (e.g., 25 mm) so as to minimize interferences between the FM and AM antennas 5 and 4.

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By properly positioning the defogging heater unit 3, AM antenna 4 and FM antenna 5 as mentioned above, the inventive glass antenna device can minimize mutual interferences between the AM antenna 4 and the FM antenna 5, between the AM antenna 4 and the defogging heater unit 3 and between the FM antenna 5 and the defogging heater unit 3.

Further, in the inventive glass antenna device, a separate subsidiary FM antenna may be provided as necessary (see Fig. 3); for example, such a subsidiary FM antenna 5s may be provided in a marginal region below the defogging heater unit 3. In this case, the FM antenna 5 may be constructed as a main antenna and the subsidiary FM antenna 5s may be constructed as a diversity antenna.

Preferably, the subsidiary FM antenna 5s also comprises a single horizontal antenna conductor element, for the same reason as set forth above in relation to the main FM antenna. It is further preferred that the subsidiary FM antenna 5s be also capacitively linked with the defogging heater unit 3. The length of this subsidiary FM antenna 5s may also be determined in the same manner as set forth above in relation to the main FM antenna. Specifically, the subsidiary FM antenna 5s may be set to a length  $L_{FMS}$  ranging from 300 mm to 500 mm.

As mentioned above, the inventive glass antenna device includes the dedicated FM antenna and AM antenna, each of which is operable independently of the other and designed basically as a straight-shaped antenna pattern. Thus, these antennas can be designed and adjusted with utmost ease.

Now, a description will be made about the amplification

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section 7.

The amplification section 7 includes the AM and FM amplifiers 8 and 9 which amplify received AM and FM signals  $V_A$  and  $V_F$  supplied via the AM and FM feeding patterns 4b and 5a of the AM and FM antennas 4 and 5, respectively. Thus, the amplification section 7 supplies the radio receiver apparatus 10 with amplified output FM and AM signals  $V_{AO}$  and  $V_{FO}$ .

More specifically, the AM amplifier 8 has a high input impedance and low output impedance and amplifies the received AM signal  $V_A$  to supply the amplified output AM signal  $V_{AO}$  to the radio receiver apparatus 10.

Fig. 4 is a circuit diagram illustrating an embodiment of the AM amplifier employed in the present invention.

In Fig. 4, the AM amplifier 8 comprises a common-source amplifier circuit, which includes an input capacitor C1, an input resistor R1, an FET (Field Effect Transistor) Q1, a load resistor R2, a choke transformer L1, a source resistor R3, and an output capacitor C2.

Because the FET Q1 has a very high input impedance, the input impedance of the AM amplifier 8 is determined by a resistance value (e.g., 1 M $\Omega$ ) of the input resistor R1 connected between the gate G and the ground GND.

Fig. 5 shows variations in noise occurring as the input resistance R1, acting as a gate resistance, is varied from 500 k $\Omega$  to 2 M $\Omega$ .

As clearly seen from Fig. 5, the noise can be reduced by setting the input resistance R1 to a small value. For instance, setting the input resistance R1 to a value of 1 M $\Omega$  or

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more will attain better results in actual use. Therefore, if the input impedance is set to a high level, the AM amplifier can effectively prevent unwanted noise from being introduced into the amplifier via the resistor R1.

5           It is also preferred that the AM amplifier be set to a low output impedance. The output impedance of the AM amplifier 8 is determined by a composite impedance of the load resistor R2 connected to the drain D and the choke transformer L1 connected in parallel with the load resistor R2.

10           Here, the choke transformer L1 includes a tap positioned at a point thereof corresponding to a 2:1 turns ratio and an output from the amplifier is extracted via this tap, so that the extracted output assumes one quarter of the composite impedance. Thus, a high-frequency transformer is preferably  
15           provided at the output stage of the AM amplifier 8, so as to cause the output impedance to be 1,000  $\Omega$  or less.

          It is preferred that the ground (GND) terminal of the AM amplifier 8 be connected to the body earth of the motor vehicle.

20           The following paragraphs describe behavior of the AM amplifier 8.

          The received AM signal  $V_A$  input to the gate G is multiplied by a voltage amplification coefficient ( $g_m$ ) of the FET Q1 and load impedance (i.e., the composite impedance of the  
25           load resistor R2 and the choke transformer L1 connected in parallel with the resistor R2), and the output from the drain D of the FET Q1 corresponds in value to a product of " $g_m \times V_A \times$  load impedance". Consequently, the output AM signal  $V_{Ao}$

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corresponds in value to one half of the product of " $g_m \times V_A \times$  load impedance".

By setting the input impedance to a high level in the above-mentioned manner, the AM amplifier 8 can effectively  
5 prevent unwanted noise from being introduced into the amplifier via the resistor R1.

Further, because the load impedance is implemented by the choke transformer, the output impedance can be set to a low value even when the amplification gain is increased. Thus, the  
10 output AM signal  $V_{A0}$  can be taken out at a high level, and also an impedance matching can be made between a coaxial cable connecting to the radio receiver apparatus 10 and the output impedance.

Note that the AM amplifier 8 may be constructed as a  
15 grounded-emitter amplifier using an ordinary transistor (and, if necessary, a darlington connection) in place of the FET.

Fig. 6 is a circuit diagram illustrating an embodiment of the FM amplifier 9 employed in the present invention.

In Fig. 6, the FM amplifier 9 is constructed as a  
20 grounded-gate amplifier circuit, which includes resistors R11, R13, an inductor L12, an FET Q2, a resistor R12, a capacitor C11 and a choke transformer L11.

Because the FET Q2 has a very low input impedance, the input impedance of the FM amplifier 9 is determined by the  
25 resistor R11. The resistor R13 and inductor L12 connected in series with each other constitute a bias circuit for the FET Q2.

The output impedance of the FM amplifier 9 is determined

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by an impedance  $Z_{F0}$  of a parallel circuit that consists of the load resistor R12 connected to the drain D, capacitor C11 and choke transformer L11. Here, the output FM signal  $V_{F0}$  is taken out via a center tap positioned on the choke transformer L11, so that the output impedance of the FM amplifier 9 equals one quarter of the impedance  $Z_{F0}$  of the parallel circuit. It is preferred that the ground (GND) terminal of the FM amplifier 9 be connected to the body earth of the motor vehicle.

Appropriate impedance matching can be made by setting the output impedance of the FM amplifier 9 ( $Z_{F0}/4$ ) to be substantially the same as an impedance of the coaxial cable connecting to the radio receiver apparatus 10.

Further, it is preferable that the FM amplifier 9 be set to a gain on the order of 0 - 3 dB so as to prevent a waveform distortion from occurring in the received FM signal  $V_F$  when the signal  $V_F$  has an excessive level. The output FM signal  $V_{F0}$  is supplied to the radio receiver apparatus 10.

In Fig. 6, a tank circuit, comprising the capacitor C11 and the choke transformer L11 connected in parallel with each other, constitutes a band-pass filter which permits a signal of the FM frequency band to pass therethrough.

In a situation where two received FM signals  $V_{F1}$  and  $V_{F2}$  of close frequencies  $f1$  and  $f2$  ( $f1 < f2$ ) would result in mutually modulated signals corresponding to a sum of the two close frequencies  $f1$  and  $f2$  ( $f1 + f2$ ) and a difference between the frequencies  $f1$  and  $f2$  ( $f2 - f1$ ), particularly where the mutually modulated signal representing the difference ( $f2 - f1$ ) assumes a frequency of the AM frequency band, the above-mentioned tank

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circuit can eliminate the mutually modulated signal representing the difference ( $f_2 - f_1$ ) to thereby effectively prevent the mutually modulated signal from being output from the amplifier and thus avoid a waveform distortion resulting from such a mutual modulation.

Thus, even when the FM signal received by the FM antenna is of an excessive level, the FM amplifier employed in the present invention can properly perform impedance conversion and signal amplification at an appropriate level without producing a waveform distortion in the output FM signal from the FM amplifier.

Further, by the capability to suppress a mutually modulated signal in the AM frequency band that would result from a mutual modulation between a plurality of output FM signals, the FM amplifier employed in the present invention can reliably prevent the output of the mutually modulated signal and thus avoid a waveform distortion resulting from such a mutual modulation.

Note that the FM amplifier 9 may be constructed as a grounded-base amplifier using an ordinary transistor in place of the FET.

The inventive glass antenna device may further include a synthesizer section 71 that synthesizes the output signals from the above-mentioned AM and FM amplifiers 8 and 9 as shown in Fig. 7.

Fig. 8 is a circuit diagram illustrating an example of the synthesizer section 71. The synthesizer section 71 includes passive components such as capacitors and inductance

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elements. The amplified output signal from each of the AM and FM amplifiers 8 and 9 is filtered so as not to flow back into the corresponding amplifier, and the thus-filtered signals are combined together or synthesized so that the synthesized result  
5 is supplied to the radio receiver apparatus 10 via the coaxial cable.

In the illustrated example of Fig. 8, the synthesizer section 71 includes capacitors C31 and C32 and choke coils L31 and L32. The synthesizer section 71 also has an AM signal  
10 input terminal connected to one end of the choke coil L32, which is connected at the other end to an output terminal of the synthesizer section 71. The synthesizer section 71 also has an FM signal input terminal connected to one end of the capacitor C31, which is connected at the other end to the  
15 choke coil L31 and capacitor C32. The other end of the choke coil L31 is grounded, and the other end of the capacitor C32 is connected to the output terminal of the synthesizer section 71.

Now, a description will be given about exemplary details  
20 of the antenna patterns employed in the inventive glass antenna device, with reference to Fig. 9.

The AM antenna 4 comprises a plurality of horizontal AM antenna conductor elements 4a that together constitute a fork-shaped AM antenna pattern. The AM antenna 4 also includes a  
25 short-cutting line 42 extending centrally across the fork-shaped AM antenna pattern. Further, a horizontal bypass element 41 is disposed above the horizontal AM antenna pattern 4a. This horizontal bypass element 41 is additionally provided

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here because there is formed a relatively large marginal gap between the upper end of the horizontal AM antenna pattern 4a and an upper window frame portion of the vehicle when the rear window glass is actually fitted in the window frame, although  
5 such a large gap is not clearly visible in Fig. 9 that is a plan of the antenna patterns as viewed from the inside of the vehicle.

Whereas the AM antenna has been described above as comprising the fork-shaped AM antenna pattern, the present  
10 invention is not so limited; for example, the AM antenna may comprise a loop-shaped antenna pattern. In the case of such a loop-shaped antenna pattern, a short-circuiting line may be provided centrally across the antenna pattern.

The following paragraphs describe specific examples of  
15 the FM antenna, either one of which may be selectively used depending on the way of power feeding to the FM antenna. More specifically, Fig. 10 A shows one example of the FM antenna that is suitable for use in the case where the FM feeding point 5a is used as the power feeding point, and Fig. 10 B shows  
20 another example of the FM antenna that is suitable for use in the case where the FM feeding pattern 5a is connected via the connecting lead. Although the designed length of the FM antenna based on the basic design specifications is the same for both the Fig. 10A example and the Fig. 10B example, the FM  
25 antenna pattern 5 of Fig. 10B is constructed to be shorter than that of Fig. 10A by an amount corresponding to the length of the connecting lead. Note that even in the Fig. 10A example, the FM antenna 5 does not extend beyond the centerline of the

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window glass.

In the above-described vehicle window glass antenna device of the present invention, each of the AM and FM antennas comprises a dedicated simple antenna pattern; thus, basic  
5 designing of these antenna patterns can be made with facility.

Typically, a region on the rear window glass where defogging is required and other regions where the glass antenna patterns may be provided are determined depending on the type  
10 of the vehicle body (such as the sedan, wagon or hatch-back type). More particularly, these regions will be determined taking into account particular design specifications, such as the size, mounting angle, etc. of the rear window glass and presence/absence of a trunk room. Thus, for a given vehicle  
15 type, the size of the window glass and the regions where the antenna patterns may be provided are determined, and then the inventive vehicle window glass antenna device is designed for application to such a window glass.

The inventive vehicle window glass antenna device can  
20 be applied appropriately to various types of motor vehicles, without changing its basic design, as long as the size and mounting areas of the window glass are similar between the vehicle types. Therefore, the necessary time for adjusting the design of the antenna device can be minimized by the present  
25 invention.

As mentioned above, the inventive glass antenna device includes the dedicated FM antenna and AM antenna, each of which

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is constructed basically as a straight antenna pattern. Thus, these antennas can be designed and adjusted with increased ease.

Further, because the FM and AM antennas are equipped  
5 with respective dedicated amplifiers, the inventive glass antenna device can receive both of FM and AM waves with high sensitivity, thereby achieving superior FM- and AM-wave reception.

Furthermore, because no choke coil has to be connected  
10 to the defogging heater unit, it is possible to reserve a wider space for mounting the antenna components and achieve reduced costs.

Moreover, even when an FM signal received by the FM antenna is of an excessive level, the FM amplifier employed in  
15 the present invention can properly perform impedance conversion and signal amplification at an appropriate level without producing an unwanted waveform distortion in the output FM signal from the FM amplifier, with the result that the FM signal can be reproduced with high quality.

20 Besides, by suppressing a mutually modulated signal in the AM frequency band that would result from a mutual modulation between a plurality of output FM signals, the present invention can reliably prevent output of the mutually modulated signal in the AM frequency band and thus avoid a  
25 waveform distortion resulting from such a mutual modulation. As a result, the FM signal can be reproduced with high quality.

In addition, in the vehicle radio receiver apparatus

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employing the inventive glass antenna, the AM and FM amplifiers are set to sufficiently low output impedances, which allows the antenna device to be connected to the radio receiver apparatus using a signal-transmitting cable having a diameter of 3 mm or less that is quite easy to handle.

Thus, it is possible to lay the signal-transmitting cable (coaxial cable) in and around the vehicle and thereby significantly reduce the necessary time and labor for assemblage.

10

#### Industrial Applicability

With the arrangements so far described, the present invention can be used advantageously as a vehicle window glass antenna device for receiving AM and FM waves with high sensitivity.

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## CLAIMS

1. A vehicle window glass antenna device comprising:

5 a defogging heater unit provided on a window glass of a vehicle;

an AM antenna provided above said defogging heater unit for receiving a signal of an AM frequency band;

an FM antenna provided between said defogging heater unit and said AM antenna for receiving a signal of an FM frequency band, said FM antenna comprising a single horizontal antenna conductor element;

AM amplifier means for amplifying the signal received via said AM antenna; and

15 FM amplifier means for amplifying the signal received via said FM antenna.

2. A vehicle window glass antenna device as claimed in claim 1 wherein said defogging heater unit is capacitively coupled with said FM antenna and functions as a subsidiary FM antenna.

3. A vehicle window glass antenna device as claimed in claim 1 which further comprises a subsidiary FM antenna provided below said defogging heater unit, and wherein said subsidiary FM antenna constitutes a diversity antenna with said FM antenna provided between said defogging heater unit and said AM antenna functioning as a main antenna.

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4. A vehicle window glass antenna device as claimed in claim 1 wherein said AM antenna comprises a plurality of horizontal antenna conductor elements.

5 5. A vehicle window glass antenna device as claimed in claim 4 wherein the horizontal antenna conductor elements of said AM antenna each have a length in the range of 800 mm to 1300 mm.

10 6. A vehicle window glass antenna device as claimed in claim 4 wherein said AM antenna includes a short-circuiting line interconnecting said plurality of horizontal antenna conductor elements.

15 7. A vehicle window glass antenna device as claimed in claim 1 wherein said defogging heater unit includes a plurality of heater lines and a short-circuiting line interconnecting the heater lines.

20 8. A vehicle window glass antenna device as claimed in claim 1 wherein said AM amplifier means comprises an electric circuit including a common-source FET and has an input impedance of at least 1 M $\Omega$ .

25 9. A vehicle window glass antenna device as claimed in claim 1 wherein said AM amplifier means includes a choke coil provided at an output stage thereof and has an output impedance of 100  $\Omega$  or less.

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10. A vehicle window glass antenna device as claimed in claim 1 wherein said AM amplifier means comprises an electric circuit including a grounded-base transistor or grounded-gate FET.

5 11. A vehicle window glass antenna device as claimed in claim 1 wherein said FM amplifier means has an input impedance of 50  $\Omega$  or less.

12. A vehicle window glass antenna device as claimed in claim 10 1 wherein said FM amplifier means has a gain of 3 dB or less.

13. A vehicle window glass antenna device as claimed in claim 1 wherein said FM amplifier means includes, at an output stage thereof, filter means in the form of a tank circuit which 15 prevents generation of a mutually-modulated signal of an AM frequency band resulting from a mutual modulation between a plurality of output FM signals from said FM amplifier means.

14. A radio receiver apparatus for a vehicle comprising:  
20 a defogging heater unit provided on a window glass of a vehicle;

an AM antenna provided above said defogging heater unit for receiving a signal of an AM frequency band;

an FM antenna provided between said defogging heater 25 unit and said AM antenna for receiving a signal of an FM frequency band, said FM antenna comprising a single horizontal antenna conductor element;

AM amplifier means for amplifying the signal received

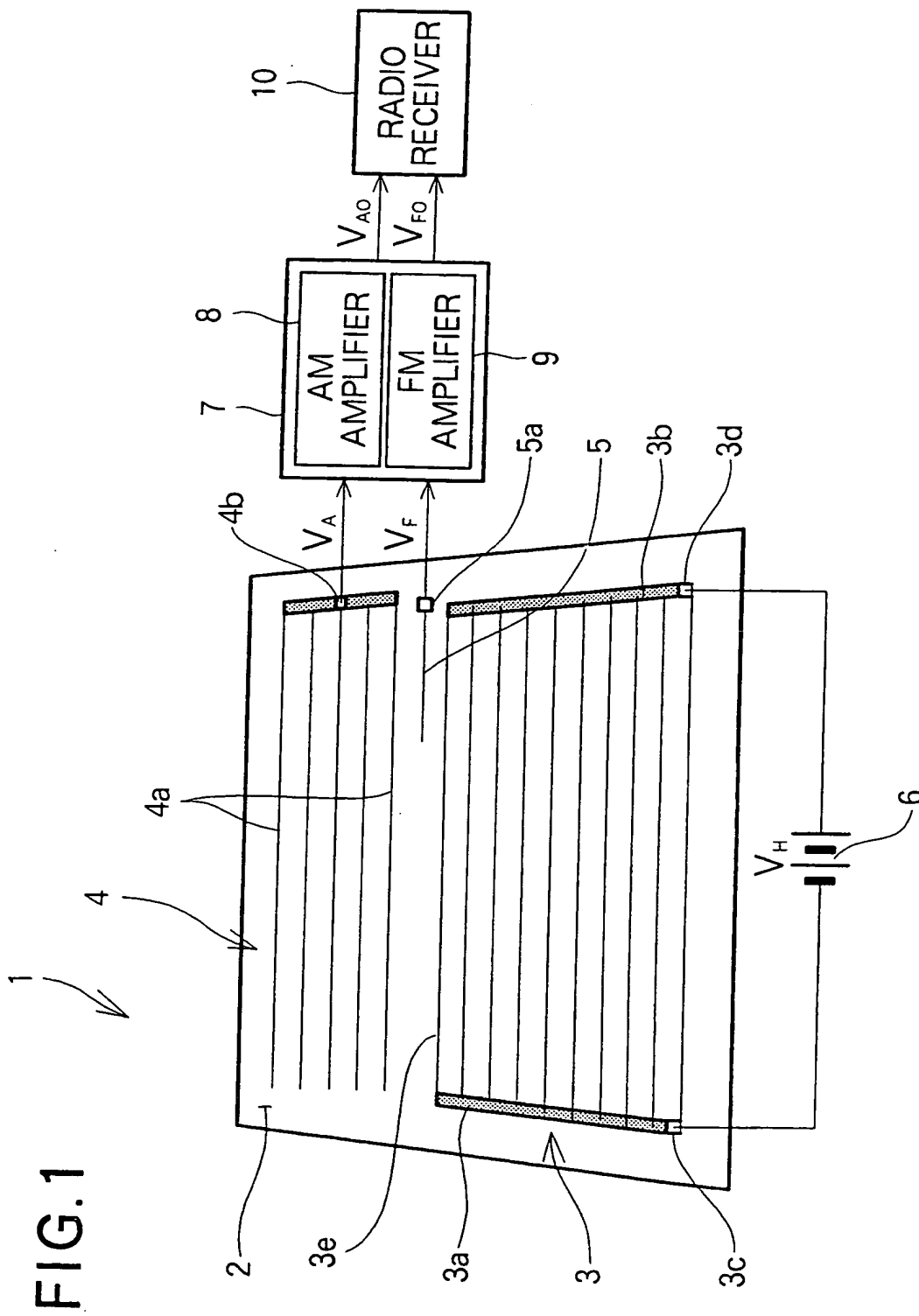
-38-

via said AM antenna;

FM amplifier means for amplifying the signal received  
via said FM antenna; and

a radio receiver connected with respective output  
5 terminals of said AM amplifier means and FM amplifier means via  
a signal-transmitting cable having a diameter of 3 mm or  
less.

15. A radio receiver apparatus as claimed in claim 14 wherein  
10 said signal-transmitting cable has an impedance of 75  $\Omega$  or  
less.



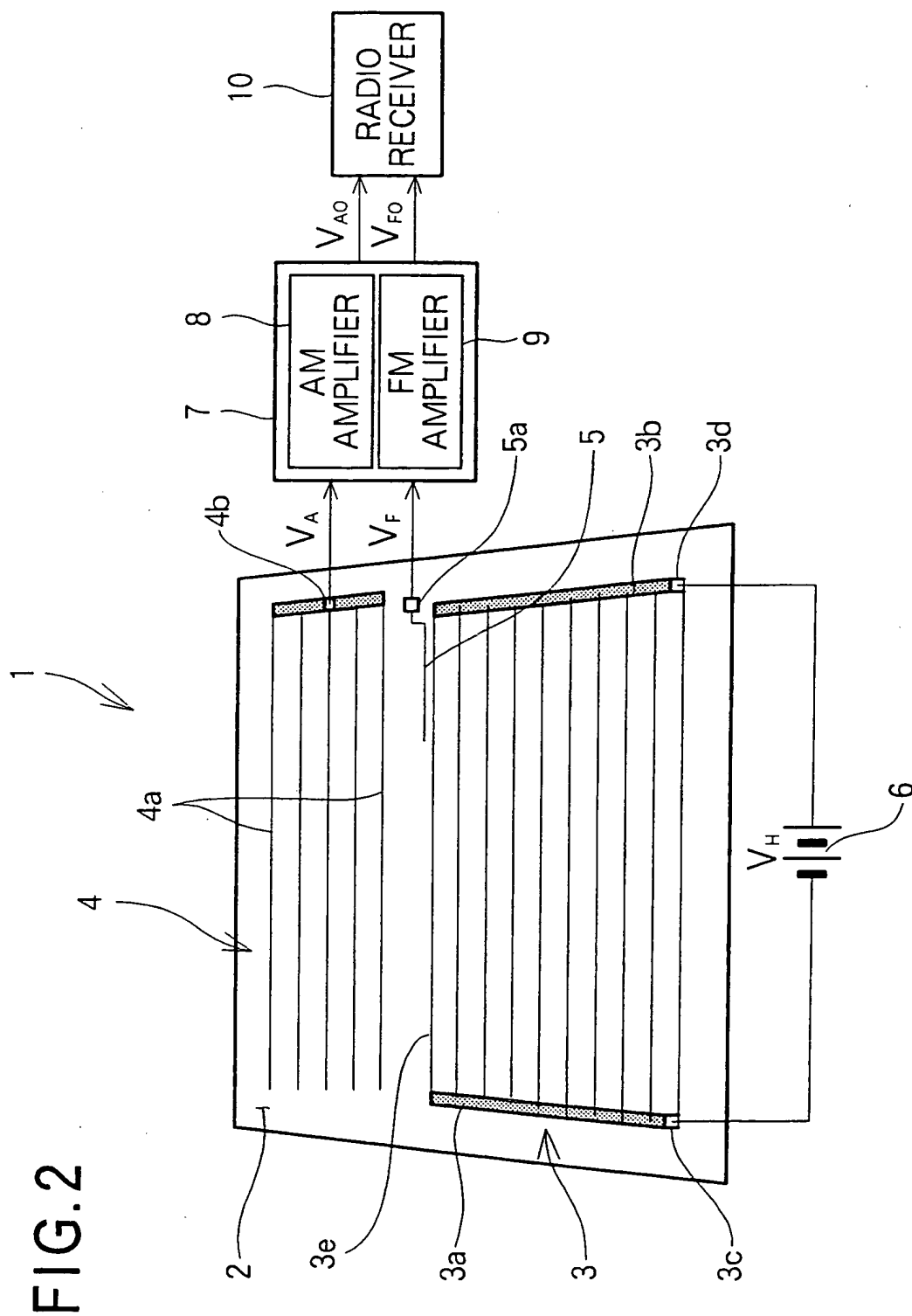


FIG.3

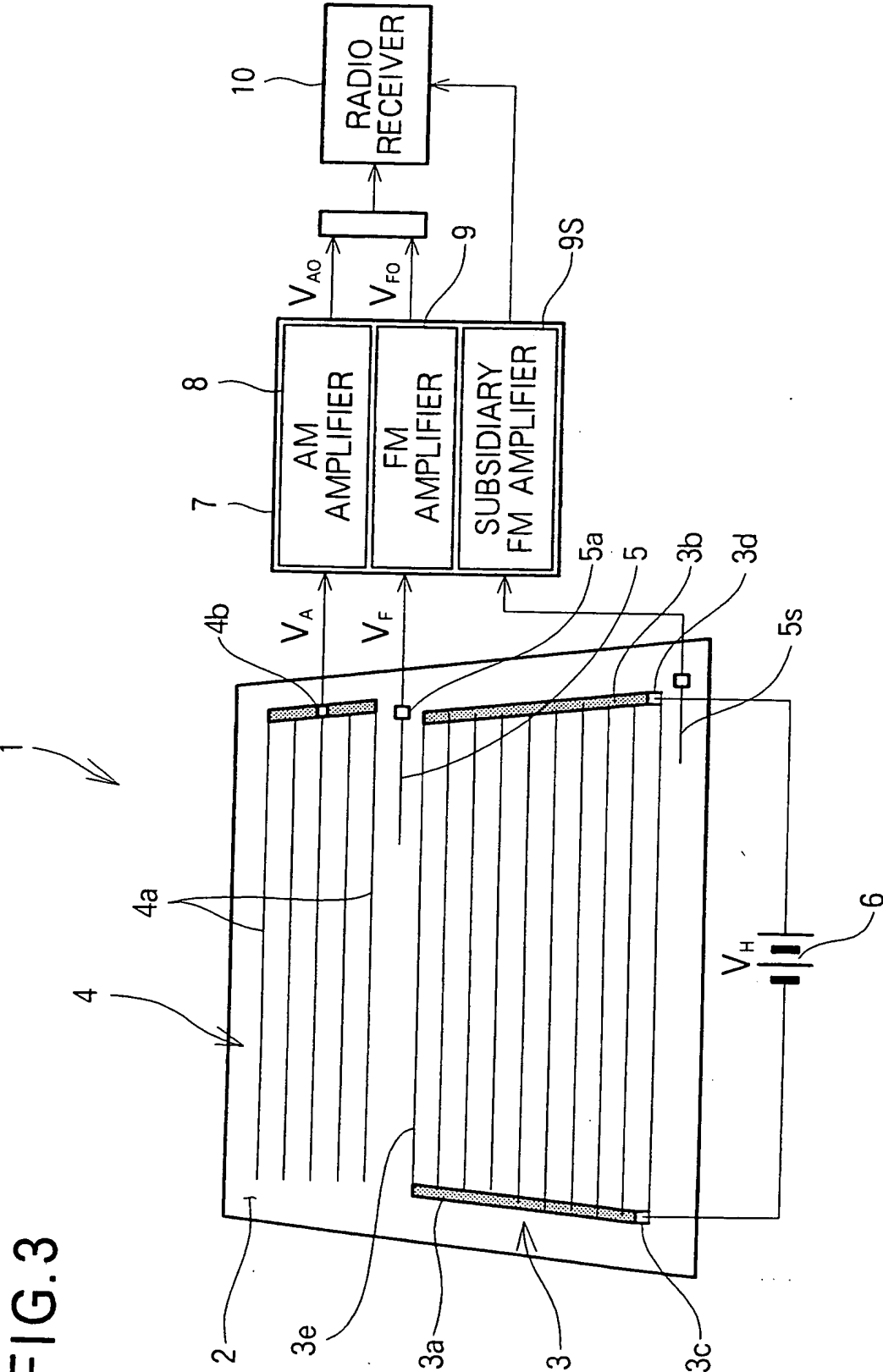


FIG. 4

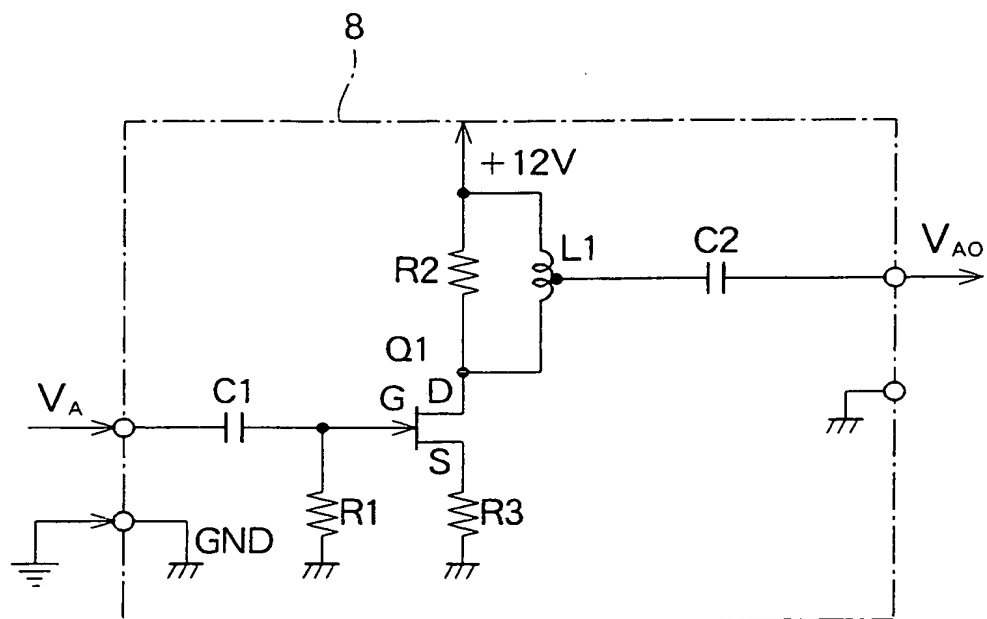


FIG. 5

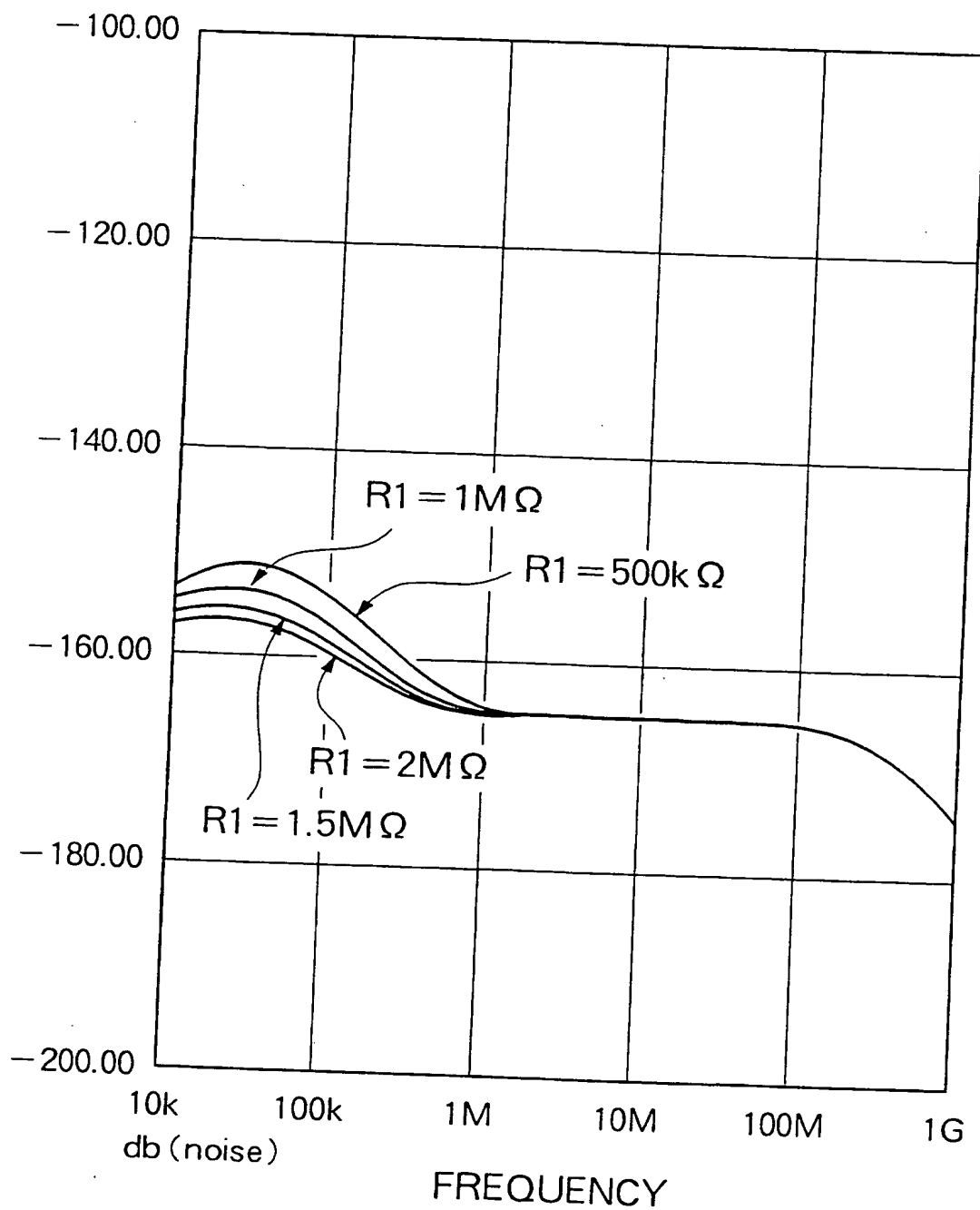


FIG. 6

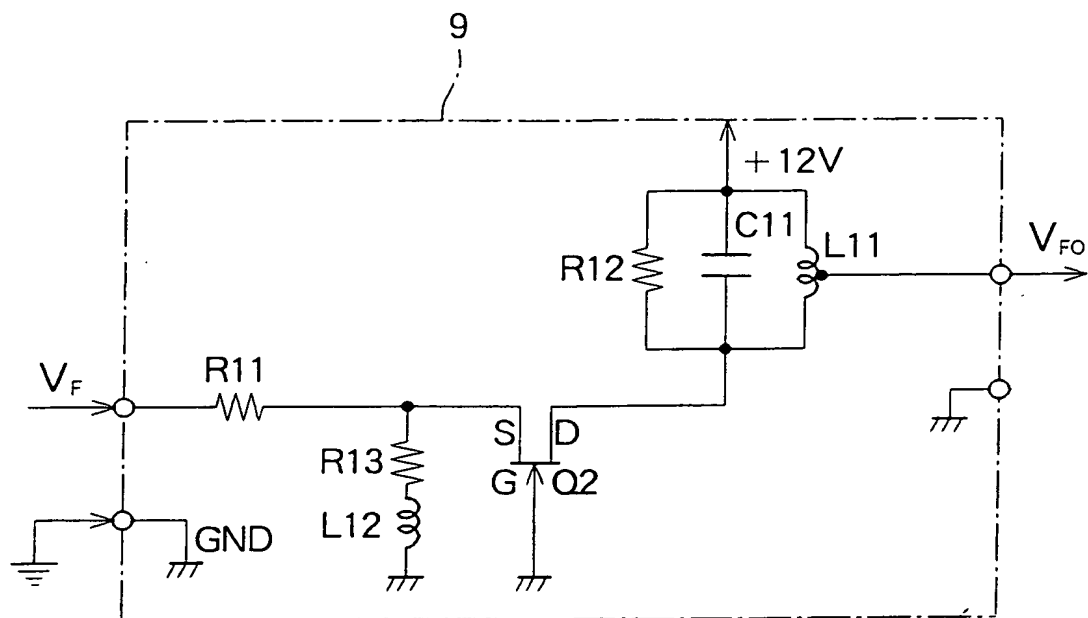


FIG. 7

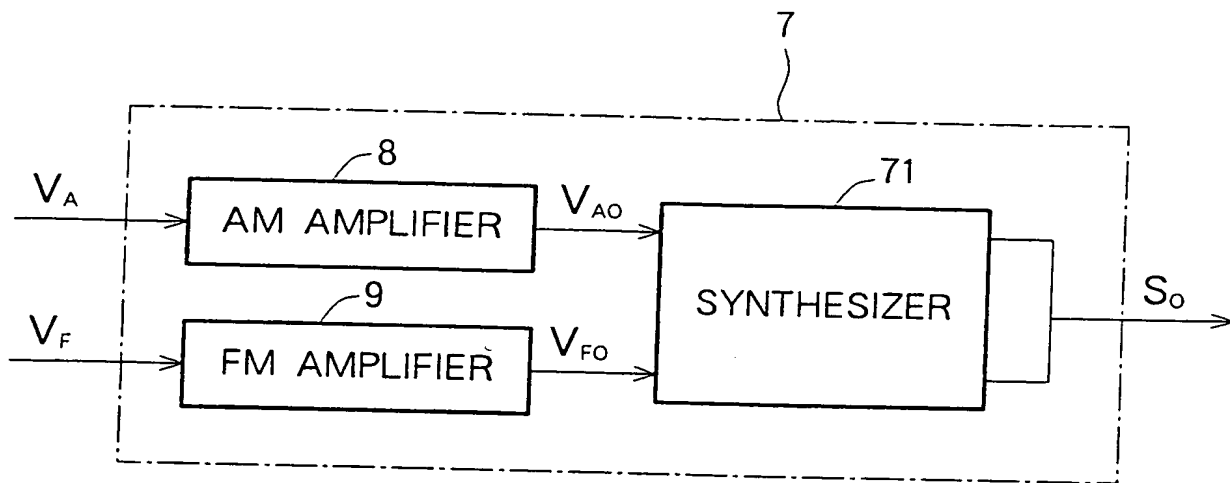


FIG. 8

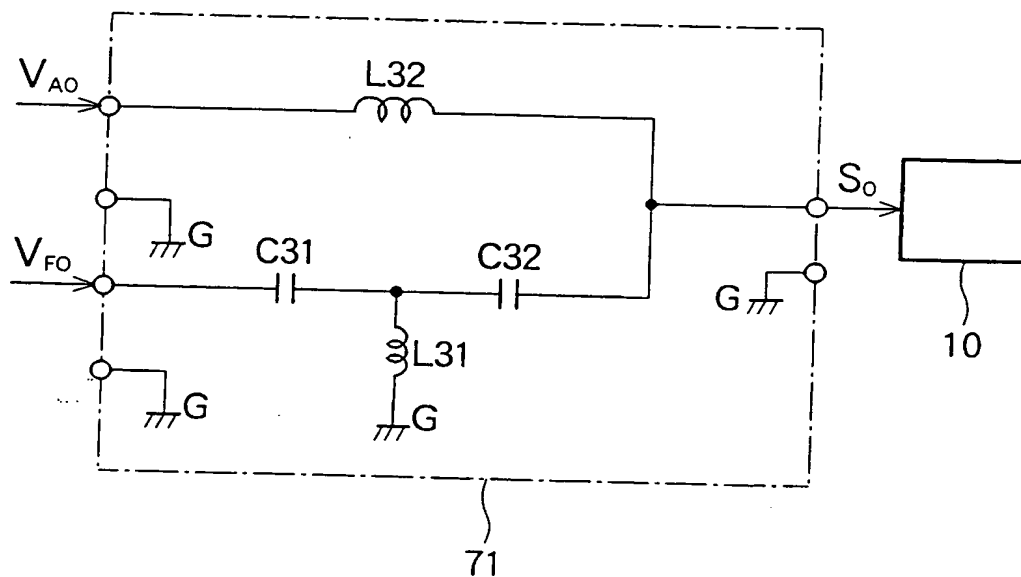


FIG. 9

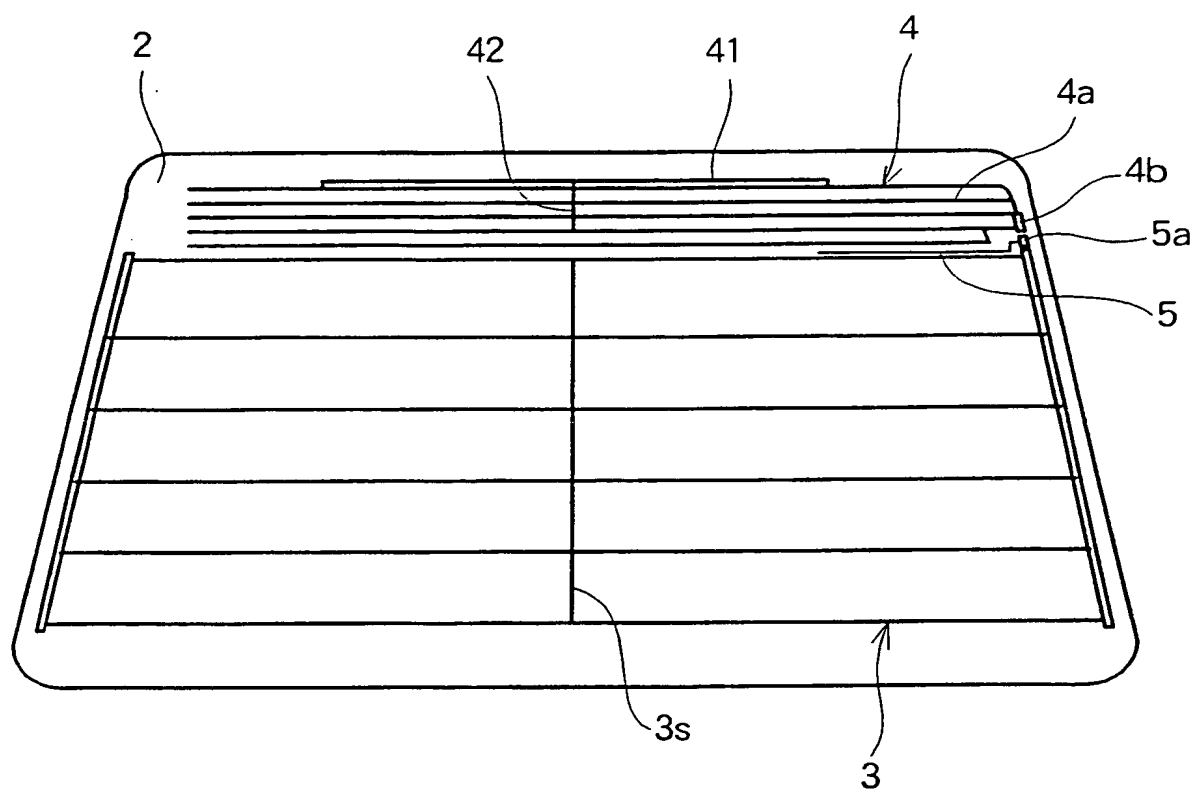


FIG. 10A

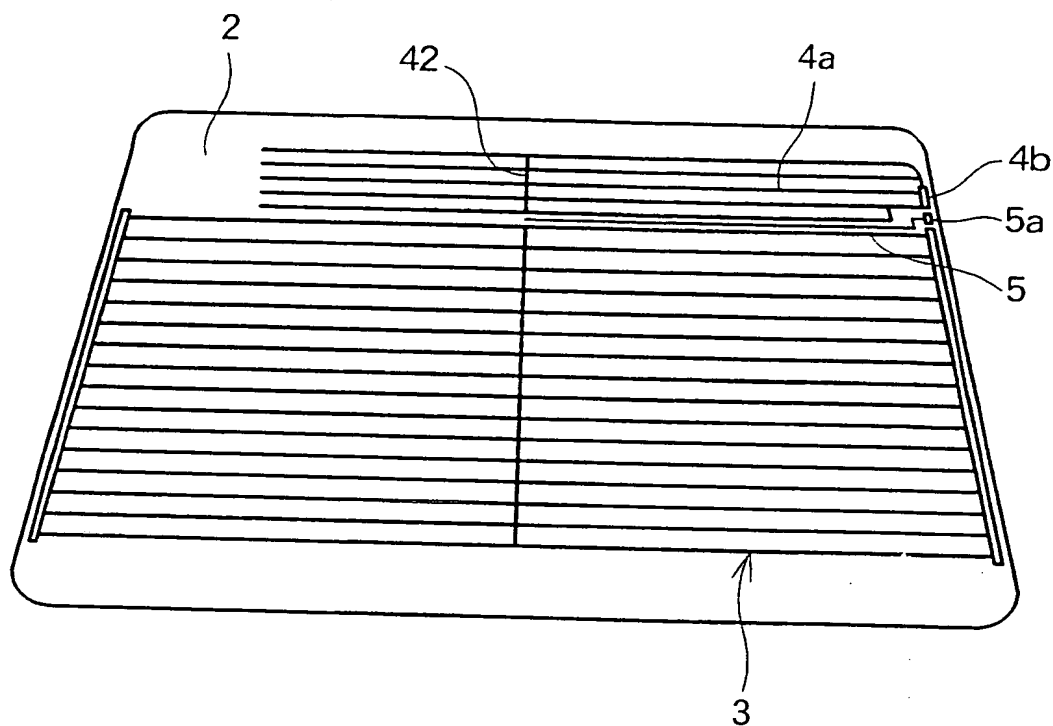


FIG. 10B

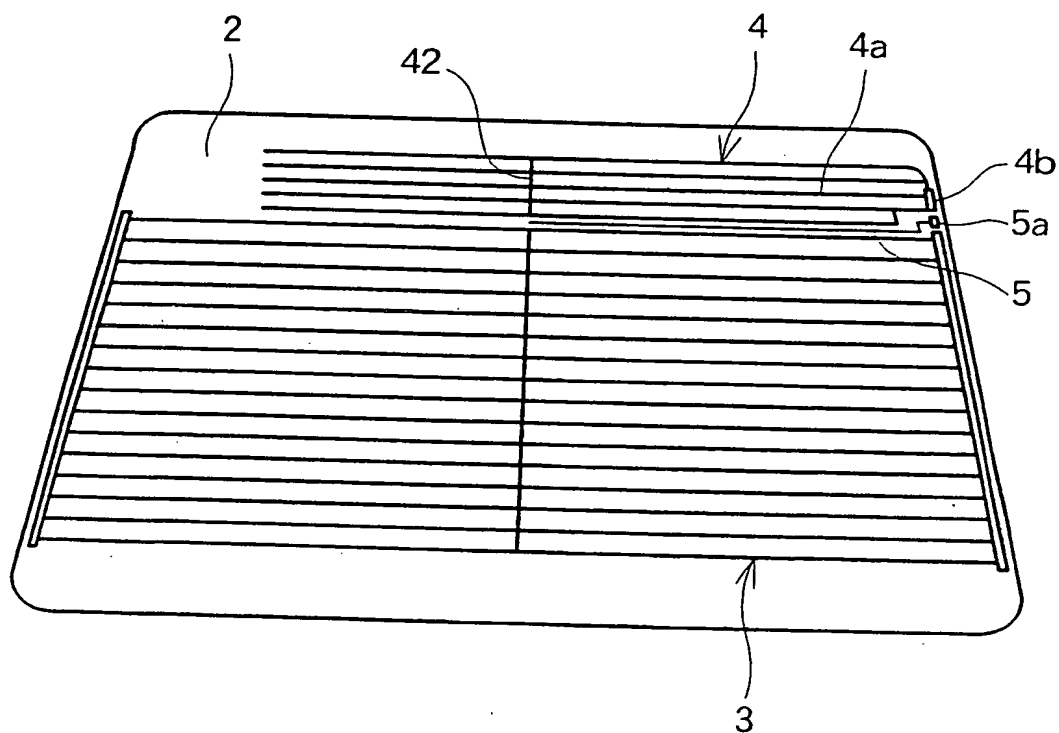


FIG. 11

(Prior Art)

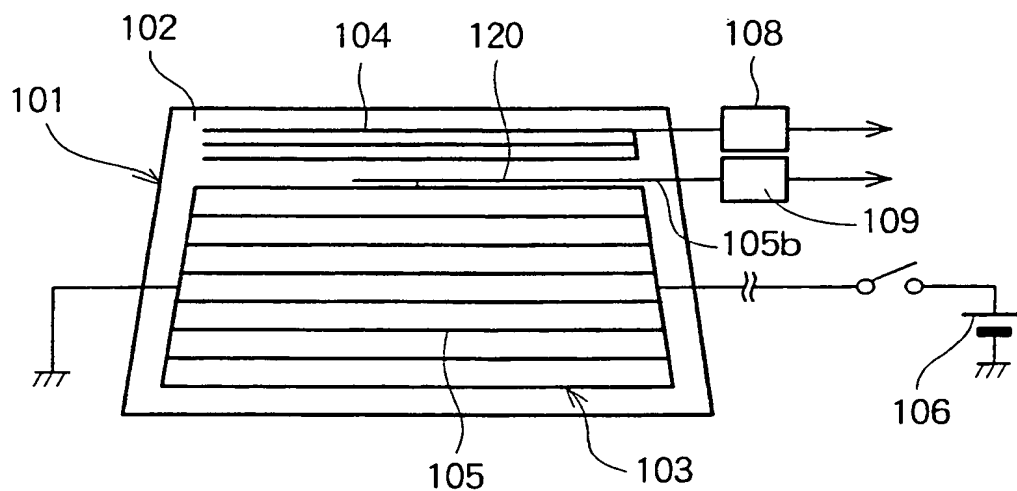
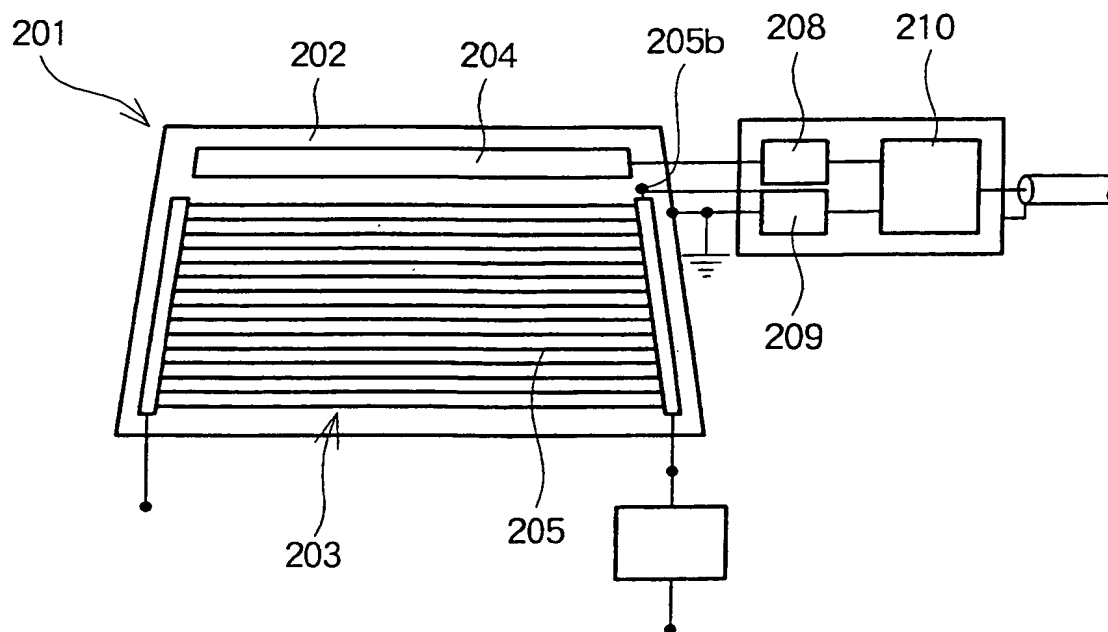


FIG. 12

(Prior Art)



# INTERNATIONAL SEARCH REPORT

Inte. n. Application No

PCT/JP 00/02827

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 H01Q1/12

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)  
PAJ, WPI Data, EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 007, no. 162 (E-187), 15 July 1983 (1983-07-15) & JP 58 070646 A (TOYOTA JIDOSHA KOGYO KK), 27 April 1983 (1983-04-27) abstract	1,2,6,14
X	GB 2 316 538 A (ANTIFERENCE LTD) 25 February 1998 (1998-02-25) page 7, line 10 -page 9, line 5; figure 3	1,2,14
X	PATENT ABSTRACTS OF JAPAN vol. 007, no. 162 (E-187), 15 July 1983 (1983-07-15) & JP 58 070644 A (TOYOTA JIDOSHA KOGYO KK), 27 April 1983 (1983-04-27) abstract	1,2,14
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

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\*8\* document member of the same patent family

Date of the actual completion of the international search

24 July 2000

Date of mailing of the international search report

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# INTERNATIONAL SEARCH REPORT

Int. Application No

PCT/JP 00/02827

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 5 408 242 A (NAKASE KAZUHIKO) 18 April 1995 (1995-04-18) column 1, line 16 -column 3, line 5; figure 6 -----	1-15

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information on patent family members

International Application No

PCT/JP 00/02827

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